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Enhanced Oil Recovery and Corrosion Inhibition through a Combined Technology of Gel Treatment for Water Shutoff and Corrosion Inhibitor Huff & Puff in Oil Well

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Abstract

In order to solve the problem of high water cut and serious corrosion in oil well, a combined technology of the corrosion inhibitor huff & puff and gel treatment for water shutoff in oil well is proposed and developed in this paper. In this technology, corrosion inhibitor solution is first injected into the oil well, then followed by selective water shutoff agent, which mothballs the corrosion inhibitor in the high permeability zone. As the oil well is resumed to produce, the succeeding water (injected water or edge water) carries corrosion inhibitor to gradually produce along medium and low permeability zone in order to achieve the multi-purpose of inhibiting the corrosion of pipe string, decreasing the water cut and increasing oil production. The optimized corrosion inhibitor and water shutoff agent were screened out for the reservoir condition before field application. The mechanisms of the new method were studied using physical simulation experiments. This technology is carried out in one well of Shengli oilfield and gets good field effect.

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Keywords: Enhanced oil recovery; Corrsoion inhibiton; Water shutoff; Gel; Corrosion inhibitor; Huff & puff

1. Introduction

With long-term development of oilfield, the water cut of oil well ascends quickly and the corrosion of oil well becomes serious which is more urgent to solve, but there is no effecitive solution for corrosion problem at home and abroad. At present, the mainly method is to add chemical corrosion inhibitors. One process is to add the corrosion inhibitor into the annulus of oil well, and the corrosion inhibitor sinks down the bottom hole by self-gravity, which was back out accompanying with produced fluid. The disadvantages of this process are: 1) Although the annulus of oil well is well protected, the inter wall of

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oil tube is in poor corrosion inhibiting effect; 2) short valid period; 3) Add corrosion inhibitor frequently. Another process is the application of solid corrosion inhibitor in oil well [1]. It is different to large-scale application because of the placement and release of solid corrosion inhibitor. So the corrosion inhibitor huff-puff is proposed for the first time, considering the selective water shutoff technology in oil well is mature, the combined technology of corrosion inhibitor huff-puff and water shut off is not only to reduce the corrosion of oil well, gathering and transferring process, but also to decrease water cut and increase oil production [2].

2. The mechanism of the combined technology

A combined technology of combined corrosion inhibiting and water shutoff is proposed in this paper, which couples corrosion inhibitor huff & puff and water shutoff in the same oil well, the diagrammatic sketch is shown in Figure 1. In this technology, corrosion inhibitor solution is first injected into the oil well, then followed by selective water shutoff agent(polymer gel), which mothballs the corrosion inhibitor in the high permeability zone and is over-displaced into formation about 3 m away from the oil well to avoid water shutoff agent to block near wellbore zone. As the oil well is resumed to produce, the succeeding water (injected water or edge water) carries corrosion inhibitor to gradually produce along medium and low permeability zone in order to inhibit the corrosion of pipe string, decrease the water cut and increase oil production. This technology fully plays their advantages and overcomes their shortcomings and has a great application prospects.

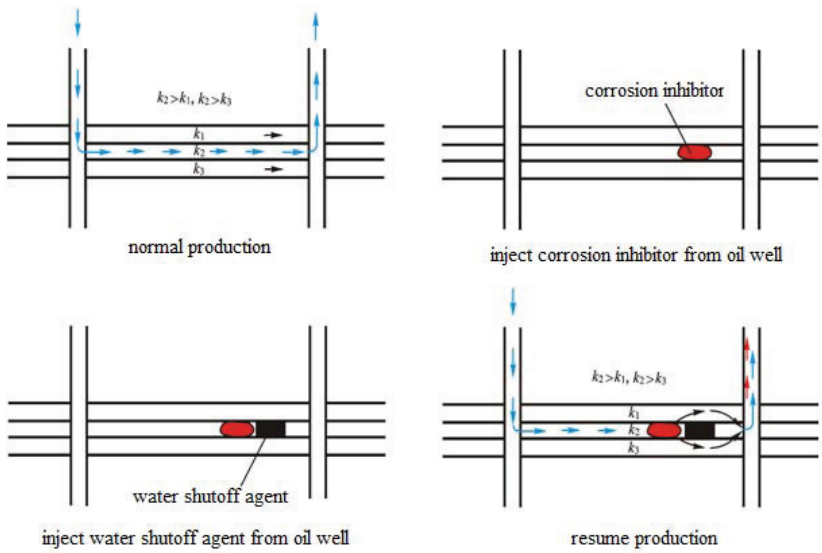

Figure 1. The diagrammatic sketch of combined corrosion inhibiting and water shutoff

3. The screening of corrosion inhibitor

Three corrosion inhibitors were evaluated by static test, and the experimental results are shown in Figure 2. From Figure 2, the corrosion inhibiting effect of CI-1 is the best. When the dosage of CI-1 is 5 mg/l, the average corrosion rate is 0.0783 mm/a, and the corrosion inhibiting rate is 70.4%; when the dosage of CI-1 is 100 mg/l, the average corrosion rate is reduced to 0.0143 mm/a and the corrosion

inhibiting rate is 94.6%. The corrosion inhibiting effect of CI-1 also was evaluated by electrochemical method. The experimental results are shown in Table 1.

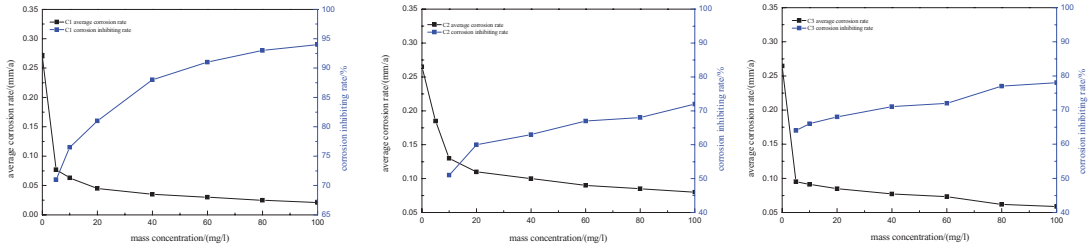

Figure 2. The corrosion inhibiting effect

Table 1. Electrochemical results after adding corrosion inhibitor

mass concentration/(mg/l)	natural corrosion potential/mV	corrosion current density/(μA/cm^2)	corrosion inhibiting rate/%
0	-704.2	121.6	—
5	-719.2	19.7	83.8
10	-685.0	13.6	88.9
20	-651.9	9.8	91.9
40	-637.8	7.1	94.2
60	-620.3	5.4	95.6

4. The screening of selective water shutoff agent

4.1. Gelation time[3]

The water shutoff agent injected into formation plays two roles: 1) mothball the corrosion inhibitor in high permeability zone, which was released slowly from low permeability zone, and extend valid period of corrosion inhibiting; 2) The water shutoff agent can block high permeability zone, increase sweep volume of water flooding and enhance oil recovery. Common water shutoff agents are shown in Table 2.

Table 2. Common water shutoff agents

type	water shutoff agent
polymer gel	chromium gel, zirconium, aluminum gel, phenolic resin gel etc
silicic acid gel	acidic silicic acid gel, basic silicic acid gel etc
precipitation	calcium silicate, magnesium silicate, calcium carbonate, magnesium carbonate etc
dispersion	foam, clay suspension, clay + cement suspension

Polymer gel among them in Table 2 is selective water shutoff agent, which is widely used in oil and gas oilfields. Chromium gel and phenolic resin gel are investigated in given condition (the temperature is

80°C; the brine is from produced water of Linnan oilfield). The experimental results are shown in Figure 3 and Figure 4. According to reservoir condition, different gelation time gel can be selected from Figure 3 and Figure 4, some of them are listed in Table 3.

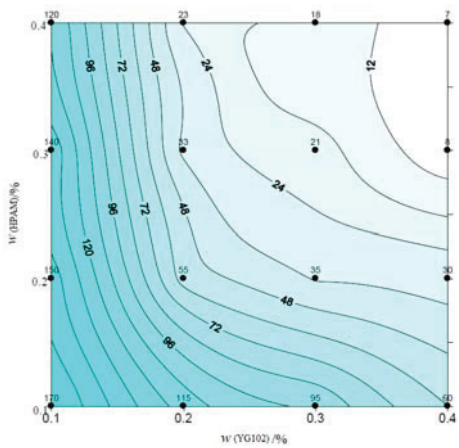

Figure 3. The contour map of gelation time of chromium gel (the value in figure is gelation time, h)

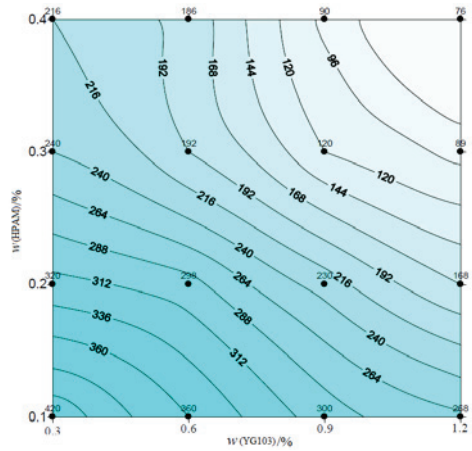

Figure 4. The contour map of gelation time of phenolic resin gel (the value in figure is gelation time, h)

Table 3. The formulas of different gelation time (80℃)

type	gelation time/day	formula
chromium gel	0.5	0.3%HPAM+0.35%YG102(I)+ 0.7%YG102(II)
	1	0.3% HPAM+0.25%YG102(I)+ 0.5%YG102(II)
	2	0.4%HPAM+0.15%YG102(I)+ 0.3%YG102(II)
phenol resin gel	3	0.4%HPAM +1.2%YG103
	5	0.3%HPAM+ 0.9%YG103
	10	0.3%HPAM+0.3%YG103

4.2. Stability in high temperature

The stability of two water shutoff agents in high temperature is studied, and the experimental results are shown in Table 4. From Table 4, we can see that phenolic resin gel has better stability than chromium gel in high temperature. So the former is suitable for water shutoff in medium and low temperature, the latter is suitable for water shutoff in medium and high temperature.

Table 4. The variation of gel in different temperature for 30 days

polymer gel formula	temperature		
	70℃	100℃	120℃
0.3%YG100+ 0.25%YG102	no variation	little free liquid on the top	badly destroyed
0.4%YG100+1.2%YG103	no variation	no variation	little free liquid on the top

5. The laboratory physical results

Separately inject 5% and 10% corrosion inhibitor (CI-1) into the models, The dimension of the model is 20 cm×20 cm×2.0 cm, which has a high permeability zone between injection well and production well with 2.0 cm width, and the permeability of this zone is separately about 5.13 μm^2 and 5.10 μm^2. The low permeability zone is separately about 1.85 μm^2 and 1.81μm^2. The mass concentration curves of produced corrosion inhibitor are shown in Figure 4 and Figure 5. From Figure 4 and Figure 5, we can see that the due to blocking high permeability zone by selective water shutoff agent, the corrosion inhibitor is released slowly and evenly from low permeability zone.

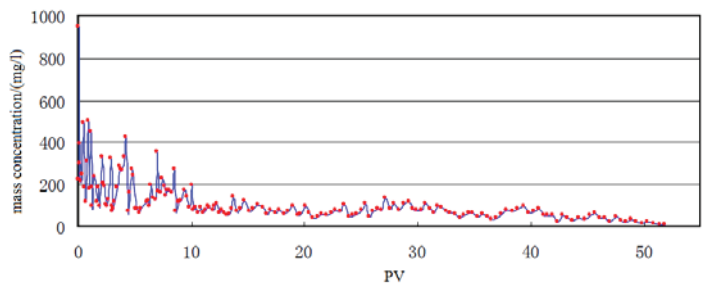

Figure 4. The mass concentration of produced corrosion inhibitor (5%)

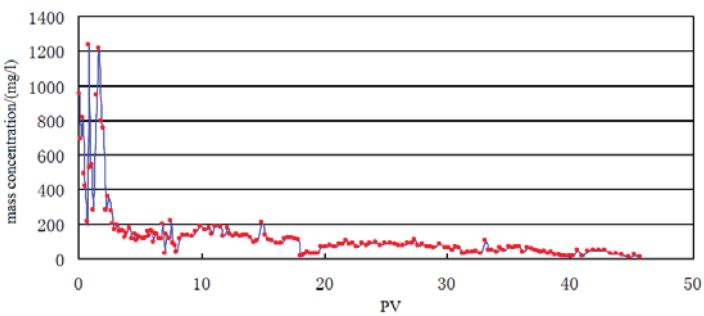

Figure 5. The mass concentration of produced corrosion inhibitor (10%)

6. Field application

In Oct 2008, this combined technology is applied in one well of Shengli oilfield. The original permeability is 69×10^{-3} μm^2, the temperature is 110°C, and the water cut of this well is over 90.0%. About 17.0 m^3 corrosion inhibitor solution with 1,700 kg corrosion inhibitor was injected to this well, then successively inject 20 m^3 sewage, 3.0m^3 selective water shutoff agent (the formula is 0.4%HPAM + 1.2%YG103) and 3.0 m^3 over-displacing fluid (0.4%HPAM). Shut-in well and resume to produce after two days, the mass concentration of produced corrosion inhibitor is shown in Figure 6. From Figure 6, we

can see that the mass concentration of produced corrosion inhibitor was from high value to constant (over 20 mg/l). From Figure 2, when the mass concentration is over 20 mg/l, the corrosion inhibiting rate is more than 80%. So this technology can effectively reduce the corrosion of oil well and gathering and transferring process, decrease water cut and increase oil production.

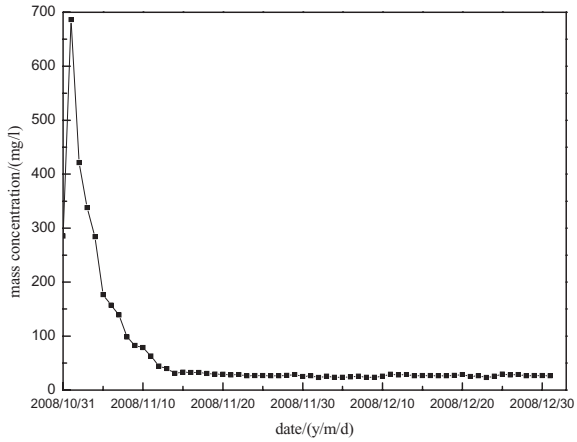

Figure 6. The mass concentration of produced corrosion inhibitor

7. Conclusions

C1 corrosion inhibitor has good corrosion inhibiting effect, when the dosage of corrosion inhibitor is over 20 mg/l, the average corrosion rate is below 0.076 mm/a and the corrosion inhibiting rate is over 80%.
Two-phase titration method is used to detect the mass concentration of C1 corrosion inhibitor both in lab and field
YG102 gel and YG103 gel are investigated in this paper, the former has quick gelation time, but latter has good stability in high temperature.
The physical simulation results show that selective water shutoff agent blocks high permeability zone, the corrosion inhibitor slowly and evenly releases from low permeability zone, expand corrosion inhibiting period.
Field test shows that this technology is not only to reduce the corrosion of oil well, gathering and transferring process, but also to decrease water cut and increase oil production.

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